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2.7 INITIAL AND BOUNDARY CONDITIONS

2.7.1 Initial Conditions

Initial conditions throughout the system are prescribed in the form of stages. For Lake Okeechobee, historical stage is used at the start of a simulation. For grid cells or nodes, initialization water levels are interpolated from observed historical data at each grid cell using a local averaging method on a basin-by-basin basis. The stage at a grid cell is the distance-weighted average of all observed data falling within a ring with whose inner radius is the distance to the nearest neighbor and thickness equal to half the grid cell diagonal. This method assures exact interpolation at the gage locations, provides zones with similar stage values, and provides smooth transition between these zones. For canals, the initial water level is assumed to be equal to the maintenance level or the historical headwater level at the downstream structure. The choice between the two options does not really make any difference as far as inferences drawn from the model output since the model is intended to be run on a long-term (several years) basis.

2.7.2 Boundary Conditions for Lake Okeechobee

Boundary conditions refer to the time series of flows or stages at the peripheral grid cells of the model. For the SFWMM, boundary conditions are applied to both the lumped representation of Lake Okeechobee and to the distributed system of grid cells forming the majority of the model domain. This section will describe the boundary conditions applied to Lake Okeechobee as seen in Figure 2.7.2.1, while Section 2.7.3 will detail the assumptions related to boundary conditions in the gridded portions of the model.

Kissimmee River Basin

Kissimmee River Basin inflow enters the north-central region of Lake Okeechobee through the S-65E structure (see Figure 2.7.2.1). The contributing basin includes the Upper Kissimmee, which covers a chain of nine managed lakes (Lakes Alligator, Myrtle, Hart, Gentry, East Tohopekaliga, Tohopekaliga, Cypress, Hatchineha and Kissimmee), and the Lower Kissimmee, which encompasses both canalized and restored reaches of the Kissimmee River. The flows through S-65E represent about 25 percent of the total Lake Okeechobee inflow.

In order to account for inflow contributions from this basin to Lake Okeechobee, a daily time-series of flows at S-65E is input into the SFWMM. This time-series is the aggregation of two independently determined values: 1) the discharge at the S-65 structure which represents the outflow for the entire Upper Kissimmee Chain of Lakes and 2) the runoff contribution provided by the Lower Kissimmee between the S-65 and S-65E structures. The means of developing these terms are discussed hereafter in greater detail.

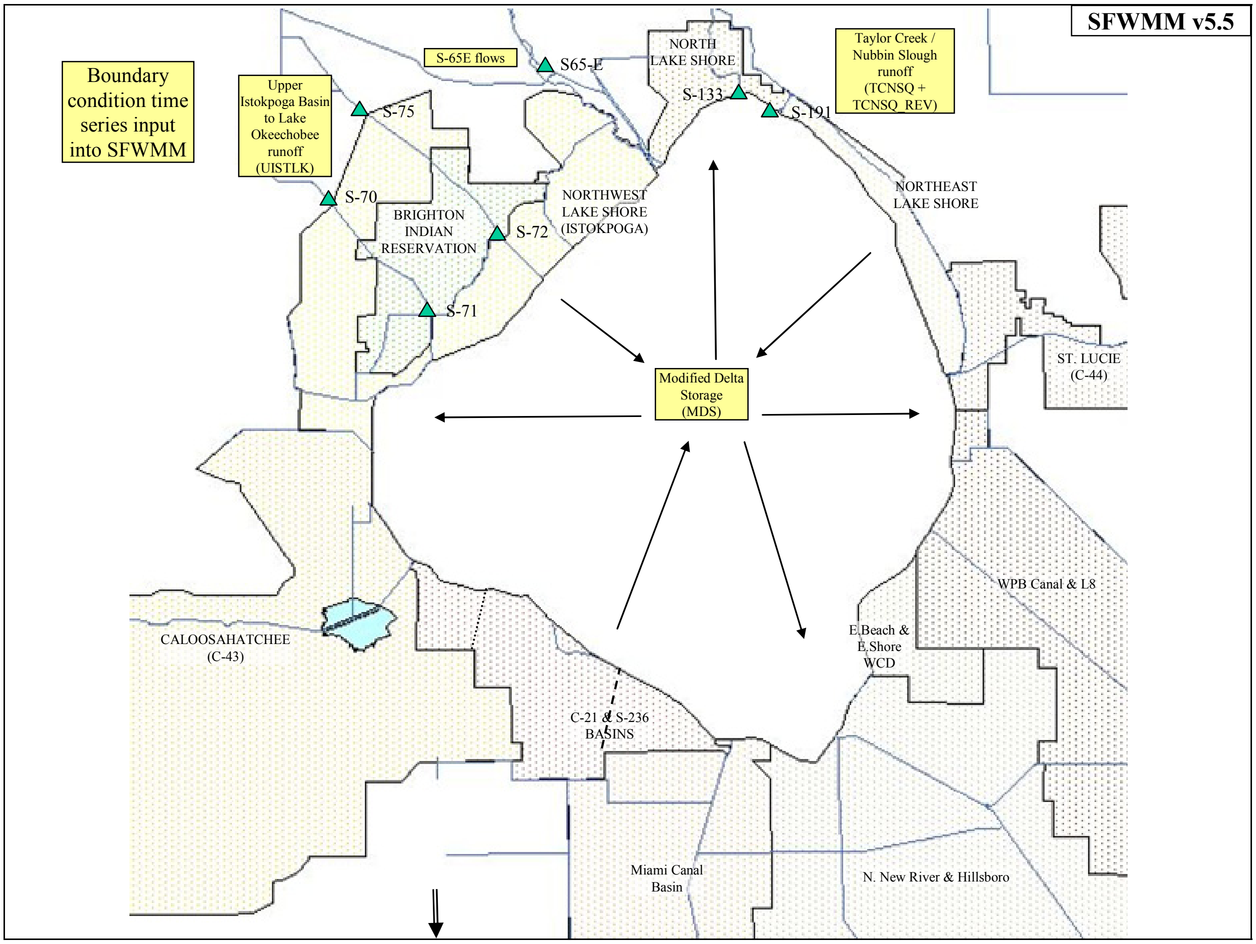

Figure 2.7.2.1 Lake Okeechobee Boundary Conditions, South Florida Water Management Model v5.5

The Upper Kissimmee Chain of Lakes Routing Model (UKISS) computer model was developed to simulate the operation of the Upper Kissimmee Basin (Figure 2.7.2.2). The model serves as a management tool to predict the lake conditions so that alternative management schemes, aimed at achieving specific objectives, can be evaluated. A Technical Memorandum for the UKISS model is provided in Appendix N. The primary output from this model from the perspective of the SFWMM is a daily time series of simulated flow at the S-65 structure.

The major assumptions and limitations of the model are presented below:

1. A primary assumption of the routing model is that level pool conditions exist. The assumption is valid as long as the flow through the lake is small relative to the storage. The assumption is reasonable under normal flow conditions but is slightly violated under heavy discharge conditions.
2. The model simulates the management of the system according to a set of management rules. These rules are expressed in regulation schedules, gate operation criteria, and established rules governing the operation of the structures. As long as the operation follows the established rules, the simulation of the management is possible. Under unusual conditions, the operation may differ from the established rules and thus explains the inability of the routing model to simulate those events.

3. The model runs in daily time steps and generates daily average flows and stages. The time step resolution is adequate for most applications except for extreme storm events where instantaneous peak stages and flows are important. Nevertheless, an examination of the recorded lake hydrographs suggests that, due to the large size of the lakes, the instantaneous stages are not significantly different from the daily averages. The errors introduced are probably small in comparison to random fluctuation of the lake stages due to wind effects and other disturbances.
4. For certain applications where only the management variables change, historical rainfall and inflow data are used. The implicit assumption is that a change in the management will not change the historical hydrologic variables.

Runoff in the Lower Kissimmee Basin is based on historical or adjusted hydrological conditions for the period of simulation. Observed runoff is computed as the difference of historical flow measurements for S-65E and S-65 flows. This calculated difference can then be added to the simulated S-65 discharges from the UKISS model to develop a time series of flow at S-65E. In some simulations, regression modeling techniques are used to adjust the historical runoff in order to account for changes in system management or climatologic conditions.

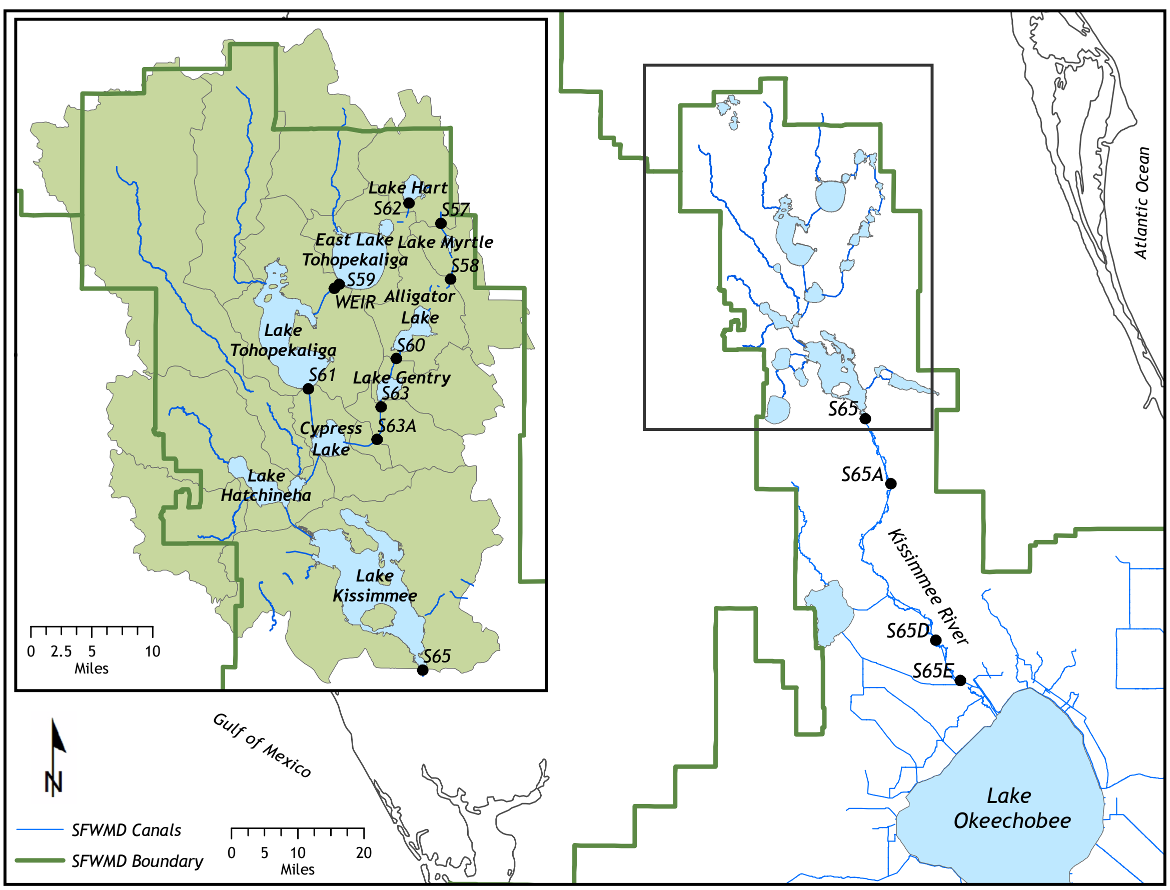

Figure 2.7.2.2 Upper Kissimmee River Basin

Upper Istokpoga Basin

The Upper Istokpoga Basin (above S70 and S75) contributes runoff into Lake Okeechobee via S70/S75 through S71/S72. This volume is made up of primarily upper basin runoff from both irrigated and non-irrigated lands in conjunction with some contribution from flood control releases out of Lake Istokpoga. In order to quantify the historical contribution of the Upper Istokpoga Basin to LOK term in the SFWMM, historical flow data for the S70, S71, S72, and S75 structures were collected. To account for lag effects between releases at the upstream structures of S70/S75 and releases at S71/S72, a monthly volumetric analysis was performed. Upper Istokpoga to Lake Okeechobee (UISTLK) contribution was quantified as the minimum of monthly combined S70/S75 and monthly combined S71/S72 flows. This calculation is sufficient to capture the flow-through contribution from the upper basin to Lake Okechobee. Once the historical monthly volumes were calculated, these volumes were temporally distributed within a given month based on the distribution observed at S71/S72 (flowing to and directly affecting the Lake). Periods of missing data (only observed at S70/S75) in the historical record were patched using a monthly regression dependent on combined current month S71/S72 flow and both current and previous month Lower Istokpoga Basin average rainfall. Regression results are presented in Figure 2.7.2.3.

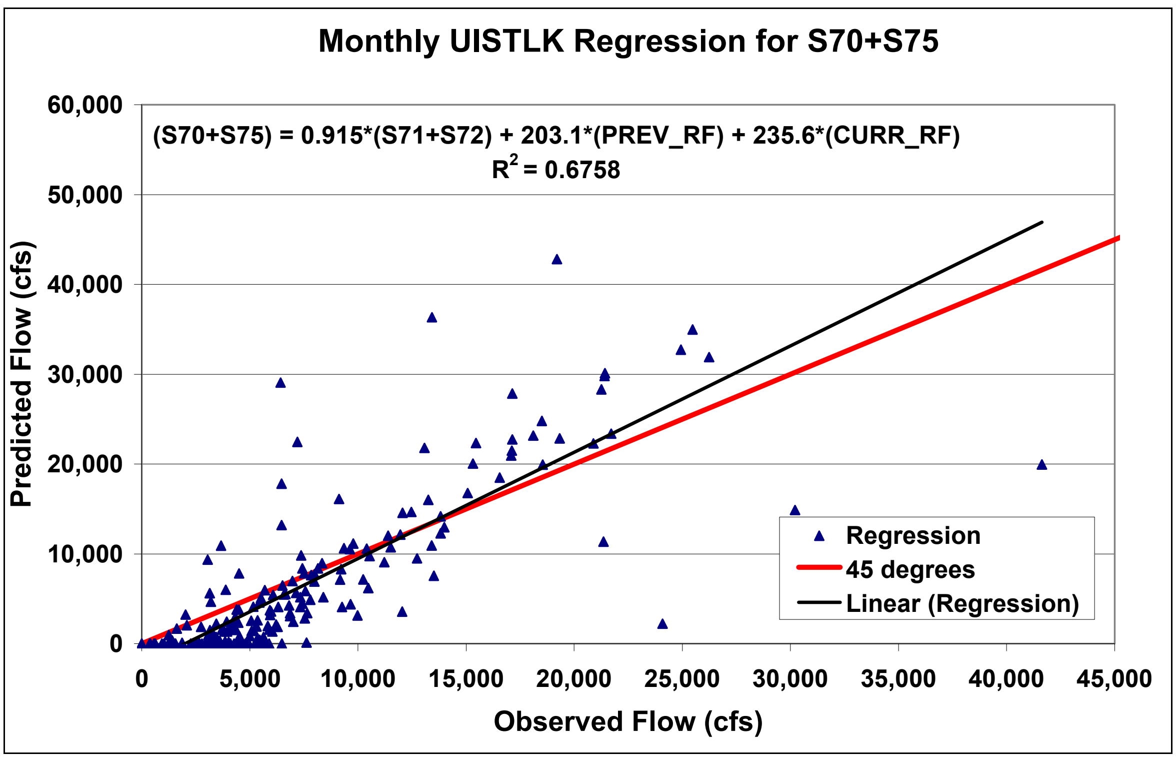

Figure 2.7.2.3 Monthly Upper Istokpoga to Lake Okeechobee Flow Regression Analysis

Taylor Creek/Nubbin Slough

The Taylor Creek/Nubbin Slough (TCNSQ) inflow term is calculated as the sum of historically observed flow at S133 and S191. In order to patch missing periods of data in the 1965-2000 period of record, a two-level analysis was performed. First, a monthly volumetric regression analysis was performed correlating TCNSQ flow to S-65E flow and both current and previous month Taylor Creek/Nubbin Slough/S133 Basin average rainfall. Once the historical monthly volumes were calculated, these volumes were temporally distributed within a given month based on a daily regression model utilizing moving averages of S-65E flow and independent average rainfall from the Taylor Creek, Nubbin Slough and S133 Basins. These moving averages were selected based on the expected response time associated with each element of the regression model (e.g. rainfall from more upstream basins would have a longer moving average than a more downstream basin). Regression results for the monthly and daily regressions are presented in Figure 2.7.2.4 and Figure 2.7.2.5, respectively. While there is not a very high correlation in the daily regression model and it tends to over-predict low flow events and under-predict high flow events, this is acceptable since its purpose is only to distribute within the volumes predicted by the more reliable monthly regression model.

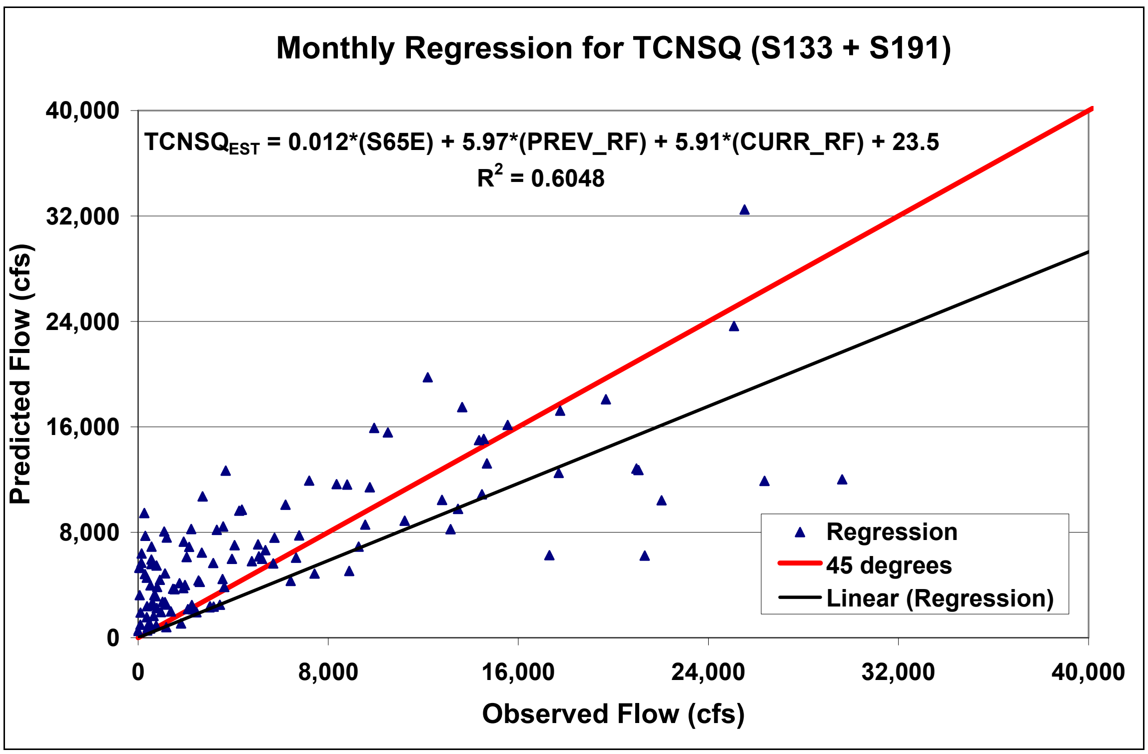

Figure 2.7.2.4 Monthly Taylor Creek/Nubbin Slough Flow Regression Analysis

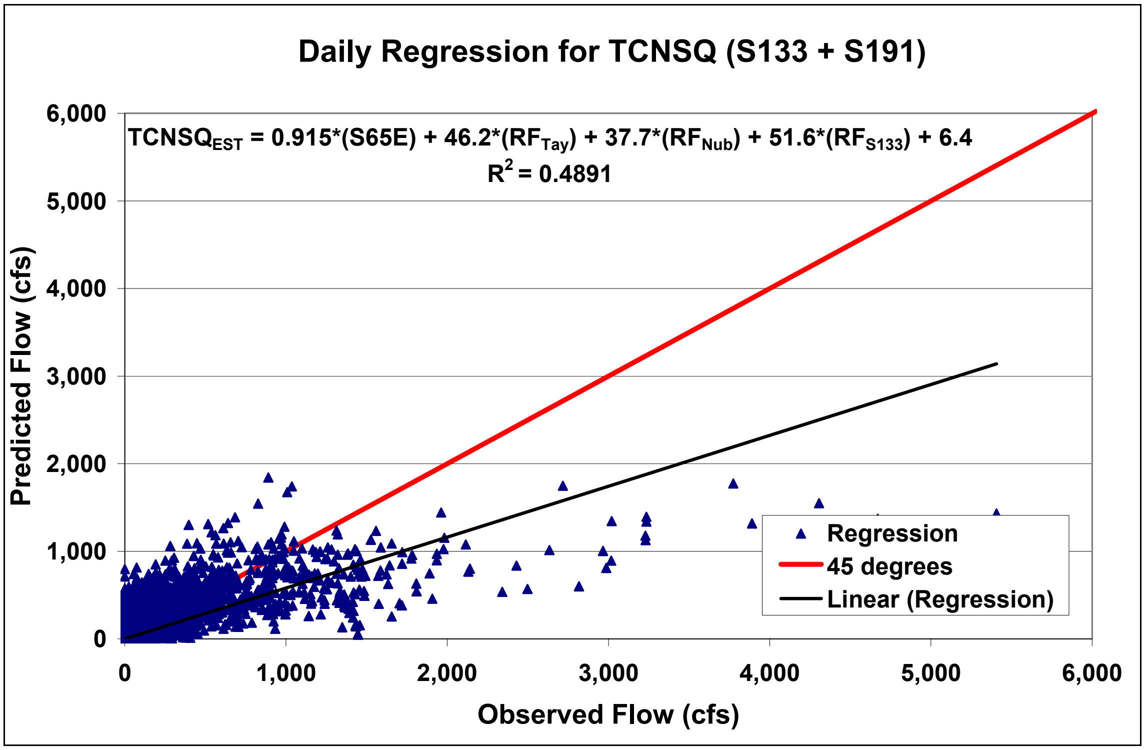

Figure 2.7.2.5 Daily Taylor Creek/Nubbin Slough Flow Regression Analysis

Lake Okeechobee Modified-Delta-Storage

One of the primary difficulties facing any tool attempting to simulate Lake Okeechobee is the challenge of representing changes in stage and corresponding storage in the absence of known or measured influence across many of the boundary conditions along the Lake perimeter. Historical data is scarce or non-existent for several structures or flow ways that represent parts of the Lake water budget. For example, runoff from Fisheating Creek is the second largest single tributary (next to Kissimmee Basin inflows) into the Lake. One difficulty in estimating inflows at this location is that measured flows are only available at the Palmdale monitoring station which is located on the upper Fisheating Creek Basin, several miles upstream of the confluence of the creek to the Lake. In order to address the inherent difficulty of accounting for flows (like Fisheating Creek) without appropriate historical boundary data, the SFWMM simulates Lake Okeechobee (as a water budget approach outlined in Section 3.1) utilizing a modified-delta-storage methodology (Trimble, 1986). A brief discussion of the approach follows, however a more detailed explanation was provided in an earlier document (SFWMD, 1999).

The modified-delta-storage (MDS) term represents the arithmetic sum of all Lake historical water budget components that: 1) are not accounted for in another simulated term on Lake Okeechobee and 2) are assumed not to change from what happened historically [Equation (2.7.2.1)]. The MDS term is calculated as follows:

$$MDS = RF^{hist} + qin^{hist} - qout^{hist} \tag{2.7.2.1}$$

where:

q = total structural flow aggregated over the current time step; and

RF = rainfall volume over the current time step.

Due to the data issues already identified, it is easier to calculate this term using knowledge of historical daily stage (storage) change and historical flow at structures that will be simulated in the SFWMM at run-time. Net levee seepage and regional groundwater movement in the Lake are assumed to be small relative to the other hydrologic components of the Lake water budget and are, therefore, not considered in the calculation of MDS. By back-calculating the MDS term as in Equation (2.7.2.2) to Equation (2.7.2.4), the historical Lake Okeechobee water budget is preserved. It is possible to begin with the historic water budget definition for the Lake (excluding seepage and regional groundwater movement):

$$delS^{hist} = RF^{hist} + qin^{hist} - qout^{hist} - ET^{hist} \qquad (2.7.2.2)$$

where:

$delS = S_{t+1} - S_t$ = change in storage from the current to the next time step; and

ET = evapotranspiration volume over the current time step.

This can be expanded to form the following equation in which some components will not change for any anticipated management/operational scenario to be evaluated in the future (subscript *NC*) and some components will change given the same scenario (subscript *C*):

$$(delS^{hist})_C = [(qin^{hist})_{NC} + (qin^{hist})_C + (RF^{hist})_{NC}] - [(qout^{hist})_{NC} + (qout^{hist})_C + (Et^{hist})_C] \qquad (2.7.2.3)$$

Rearranging this equation and substituting Equation 2.7.2.1 gives:

$$(delS^{hist} - qin^{hist} + qout^{hist} + ET^{hist})_C = (RF^{hist} + qin^{hist} - qout^{hist})_{NC} = MDS \qquad (2.7.2.4)$$

Note that the equation above illustrates the ability to calculate the MDS term using an aggregation of historically observed Lake storage change, structure flow for stations that will be simulated (subscript *C*) and historical ET measurement. All of these terms can be easily obtained or estimated.

The static nature of components that are retained in the MDS term can be attributed to the following factors:

1. the management/operational scenario being analyzed may not significantly impact, if at all, those particular components;
2. even if they do, the components themselves may be too small in magnitude in comparison with the others such that neglecting them may be a reasonable assumption; and
3. there may be no means of quantifying them within reasonable certainty.

2.7.3 Other Boundary Conditions

The boundary conditions applied to the gridded portions of the SFWMM are graphically illustrated in Figure 2.7.3.1. The general southeasterly direction of both natural (overland and groundwater flow) and man-controlled (structure discharge) flows in South Florida allows the northern boundary condition of the distributed mesh to be defined in terms of historical or independently simulated flows depending on the scenario simulated. On the northeastern boundary along the Martin-Palm Beach County line a no-flow boundary condition is assumed for both overland flow and groundwater flow. A no-flow boundary condition for both surface water and groundwater is imposed on the northwestern and midwestern boundaries except for basins tangent to the SFWMM which provide single point inflows into the model. These basins, collectively known as the Western and Feeder Canal Basins, are presented in additional detail below.

The southwestern portion of the model domain, where the model cuts the western portion of the Everglades National Park (ENP), is defined as a no-flow boundary as far as groundwater movement is concerned. On the surface, a uniform overland flow condition is imposed, as the hydraulic gradient or water surface profile is always assumed to be parallel to land surface. At the later part of this section, the tidal boundary is discussed. Along the eastern seaboard several tidal stations had adequate data available. Along the southern rim of the ENP, tidal boundary data were developed. The tidal boundary data values are passed to the groundwater subroutine as known head boundary conditions.

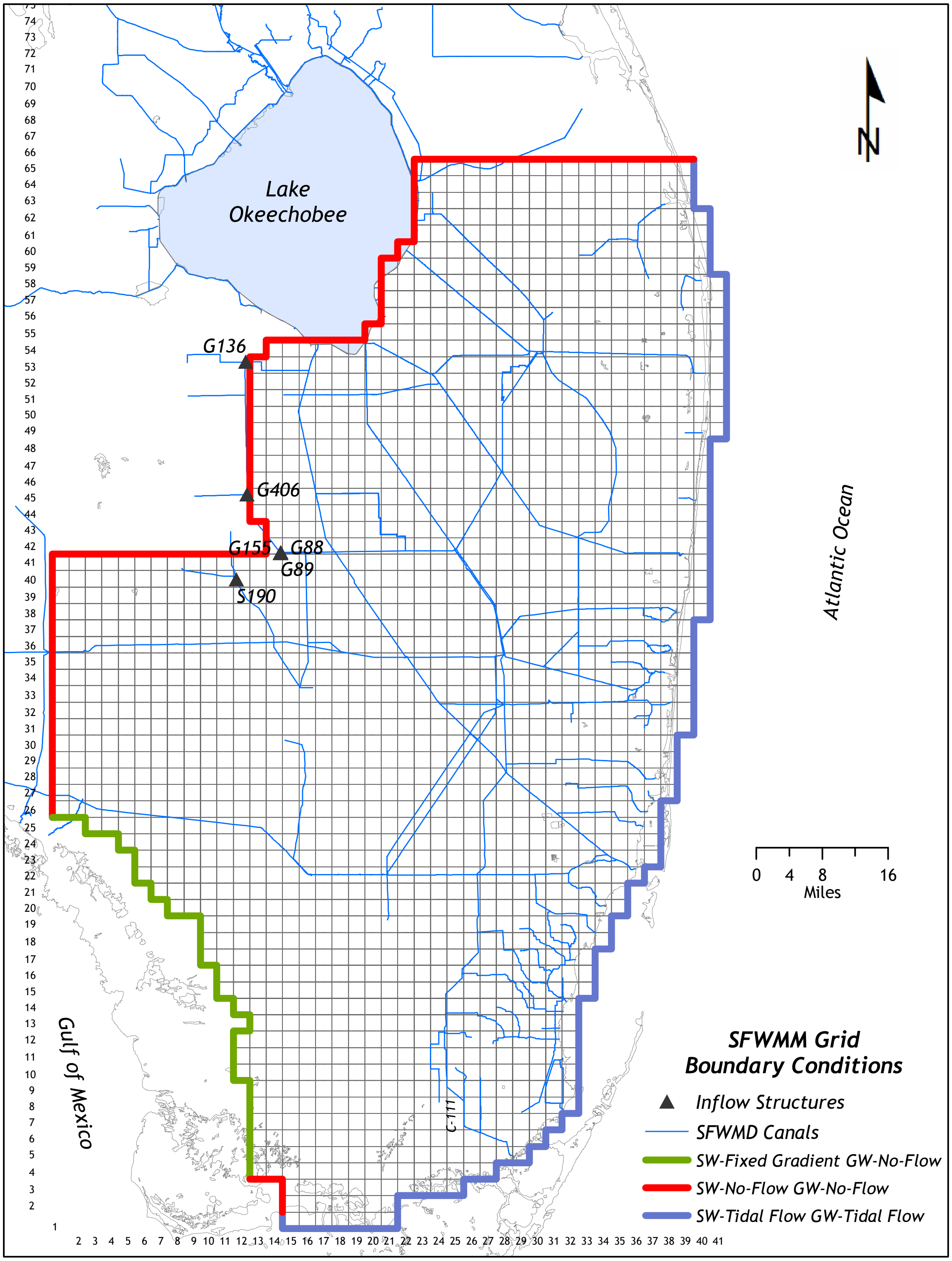

Figure 2.7.3.1 South Florida Water Management Model Gridded Boundary Conditions

Western Boundary Flows at the L-1 and L-3 Canals

This section describes the criteria and procedures followed to obtain Western Boundary flows at the L-1 and L-3 Canals for the SFWMM simulations. These flows are not always intended to reflect historical values, but rather flows that would be obtained if climatological conditions for the period 1965-2000 were repeated, given infrastructure and operations of the system that were in place circa 2000 (Cadavid and Brion, 2002). Flow time series needed as boundary inflows to the SFWMM are given at several different locations (see Figure 2.7.3.2):

- G-136, representing flows from the L-1 Canal and the C-139 Basin. These flows will be directed to the EAA and will not enter STA-5.
- G-406, representing flows from the C-139 Basin. These flows will be potentially diverted into STA-5, depending on model user input.
- Historical flows from the L-3 are prescribed at three locations: G-88, G-155 and G-89. Flow routing at these structures is dependent on user input and simulated features. G-88 flows can be directed to the EAA, STA-5 or STA-6. G-155 flows are sent to STA-5 or into northwest WCA-3A. G-89 flows are directed to STA-5 or to central WCA-3A via the L-4 Canal and the S-140 structure.

Other flow monitoring locations playing an important role in this analysis are the L3DF and L3BRS UVM (Ultrasonic Velocity Meter) locations. L3DF is located on the L-3 Canal slightly downstream of the current G-406 location. L3BRS is located on the L-3 Canal just upstream of the G-88, G-155 and G-89 structures.

The flow data set used in the C-139 Basin Rulemaking process is comprised of flows at G-136 and G-406 locations for the period October 1978 through April 2000 (Walker, 2000a). The input data set for SFWMM simulations is comprised of flows at the locations described above for a longer period of time: January 1965 through December 2000 (December 1995 for the ECP simulations). The construction of flow time series for the SFWMM follows closely the procedures applied for assembling the flow data set for the C-139 Basin Rule (Walker, 2000a, 2000b).

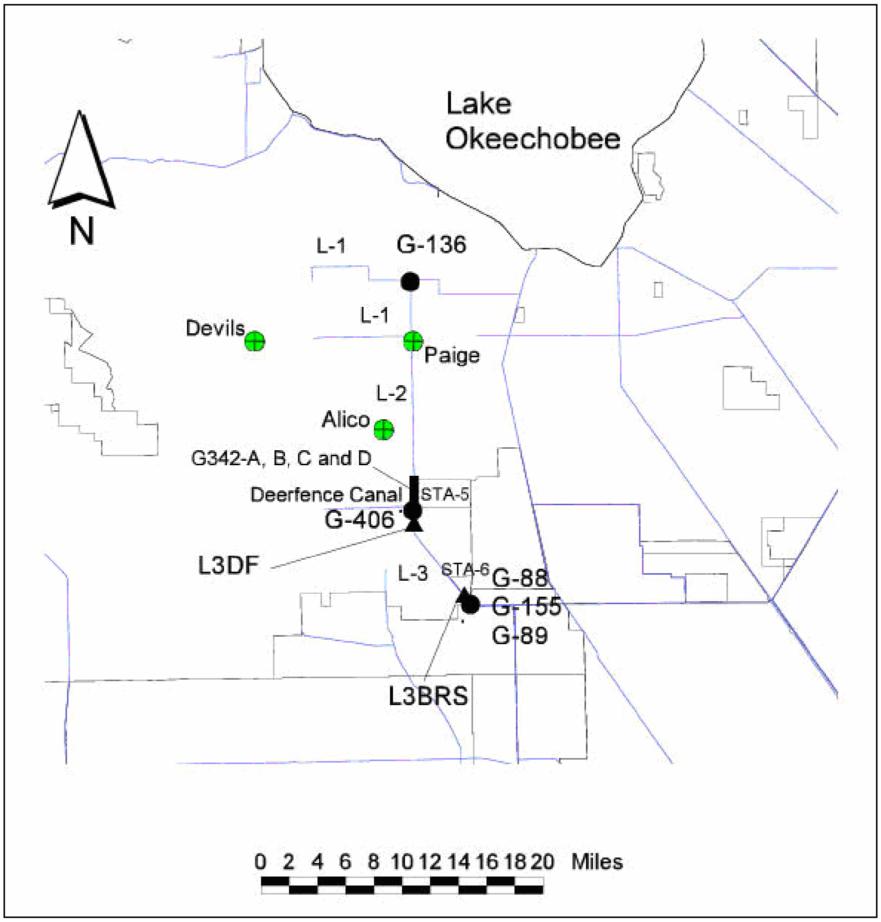

Figure 2.7.3.2 Schematic Representation of the L-3 Flow Locations

S190 Boundary Flows

South of the Western Basins, an additional structural boundary flow into the SFWMM is applied at structure S-190. A 36-year continuous time series (1965-2000) of daily runoff at S-190 is estimated using the AFSIRS/WATBAL model on the Feeder Canal Basin. It is assumed that local runoff from the Feeder Canal Basin could potentially be routed to the S-190 structure located downstream of Seminole Big Cypress Reservation irrigated lands (Figure 2.7.3.3). On a daily time step, the projected Reservation irrigation demands are compared to the estimated S-190 flows. If there is available water in the Feeder Basin, it is used to meet Reservation demands and the boundary discharge at S-190 is decreased accordingly to preserve the water budget. The revised estimated S-190 flows are a boundary condition in the SFWMM, while the revised supplemental demand time series are input to the model to be met by the regional system. On an average annual basis over the 36 year period, approximately 3,870 ac-ft/yr of water is captured upstream of S-190 for use by Seminole Big Cypress lands. This volume represents roughly 13.6% of the total 28,510 ac-ft/yr of supplemental irrigation demand.

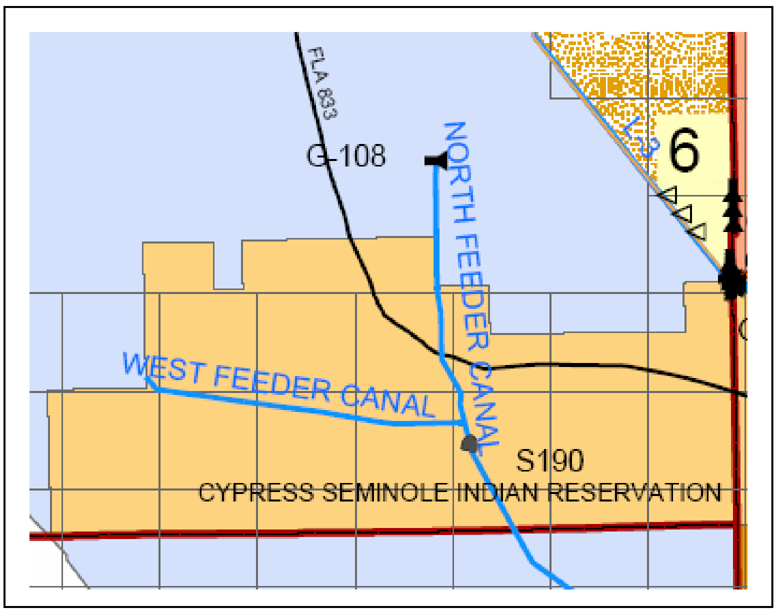

Figure 2.7.3.3 S-190 in Relationship to Seminole Big Cypress Reservation

Tidal Boundaries

Raw data from the National Oceanic and Atmospheric Administration/National Ocean Service (NOAA/NOS) were selected to create the tidal data set for the SFWMM. This sub-section presents a quick overview on how the data has been collected and treated.

To develop and evaluate the tidal data needed, the following steps were taken: (1) Collect historical data available to create tidal boundary file for SFWMM; (2) use NOAA/NOS Products and Services Division coefficients to simulate tidal data for secondary stations where historical data are not available (Table 2.7.3.1 and Figure 2.7.3.4); and (3) transform NOAA/NOS four historical daily values and hourly values to mean monthly. The 36 years (1965 to 2000) of daily data sets for each station were reduced to 12 monthly average values. The final data sets used to define the SFWMM tidal boundary for the east coast and the south east region of the model domain are shown in Figure 2.7.3.5. The model interpolates daily values from the monthly values, then the daily tidal data are passed to the groundwater routine as known head boundary conditions.

Table 2.7.3.1 Constants from the National Ocean Service Products and Services Division used to Compute Water Level for the Secondary Stations

Tidal station	Time		constant
	High Water	Low Water	
Flamingo Bay	3 hr 5 min	4 hr 28 min	0.837
Main Key	1 hr 3 min	1 hr 58 min	0.163
Virginia	Reference station		
Hollywood Beach	8 min	15 min	1.017
Delray Beach	53 min	1 hr 16 min	1.243
Palm Beach	-41 min	-35 min	1.365
Stuart	1 hr 44 min	2 hr 41 min	0.483

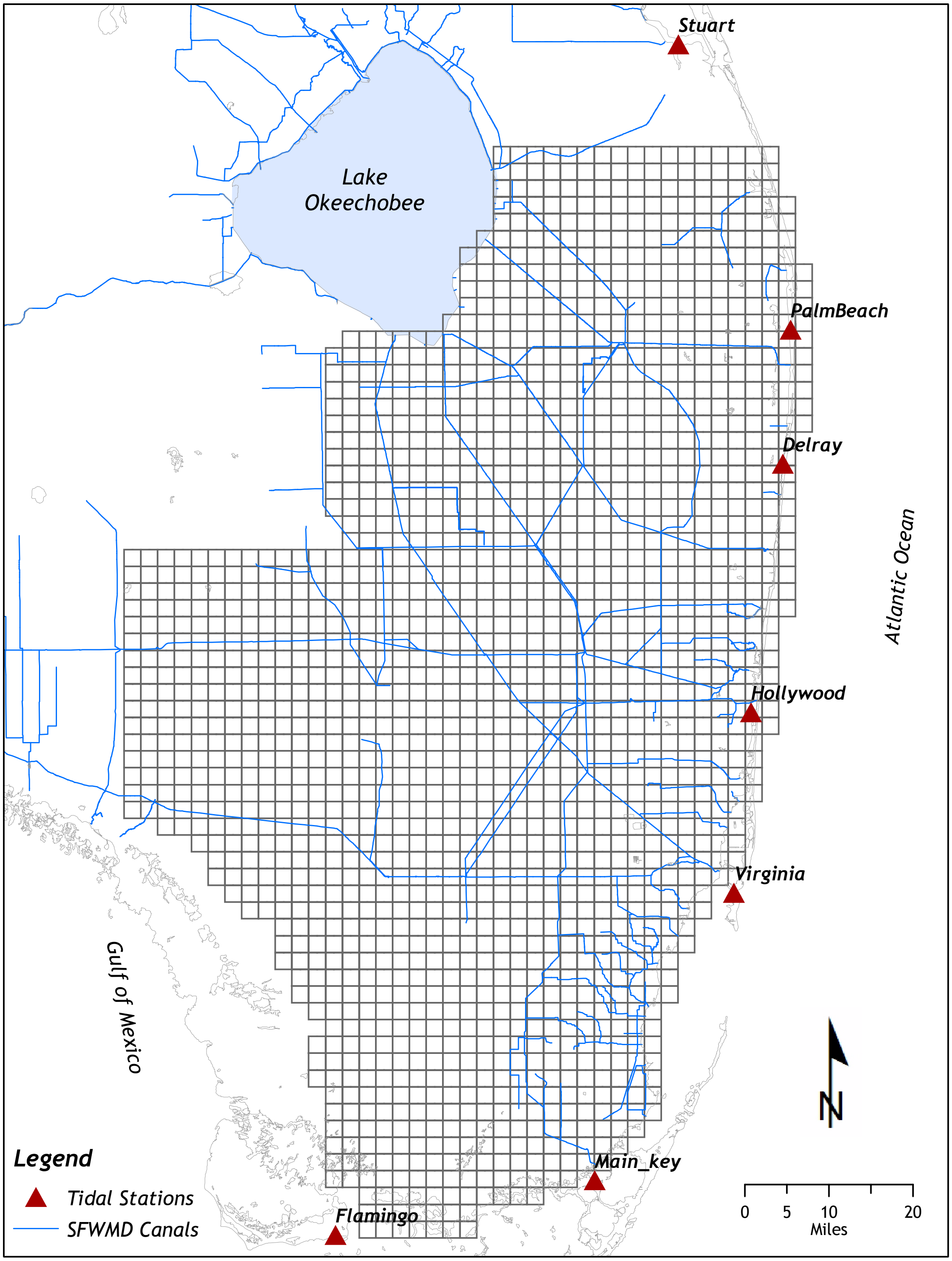

Figure 2.7.3.4 Tidal Stations Used to Define Coastal Boundary Conditions for the South Florida Water Management Model

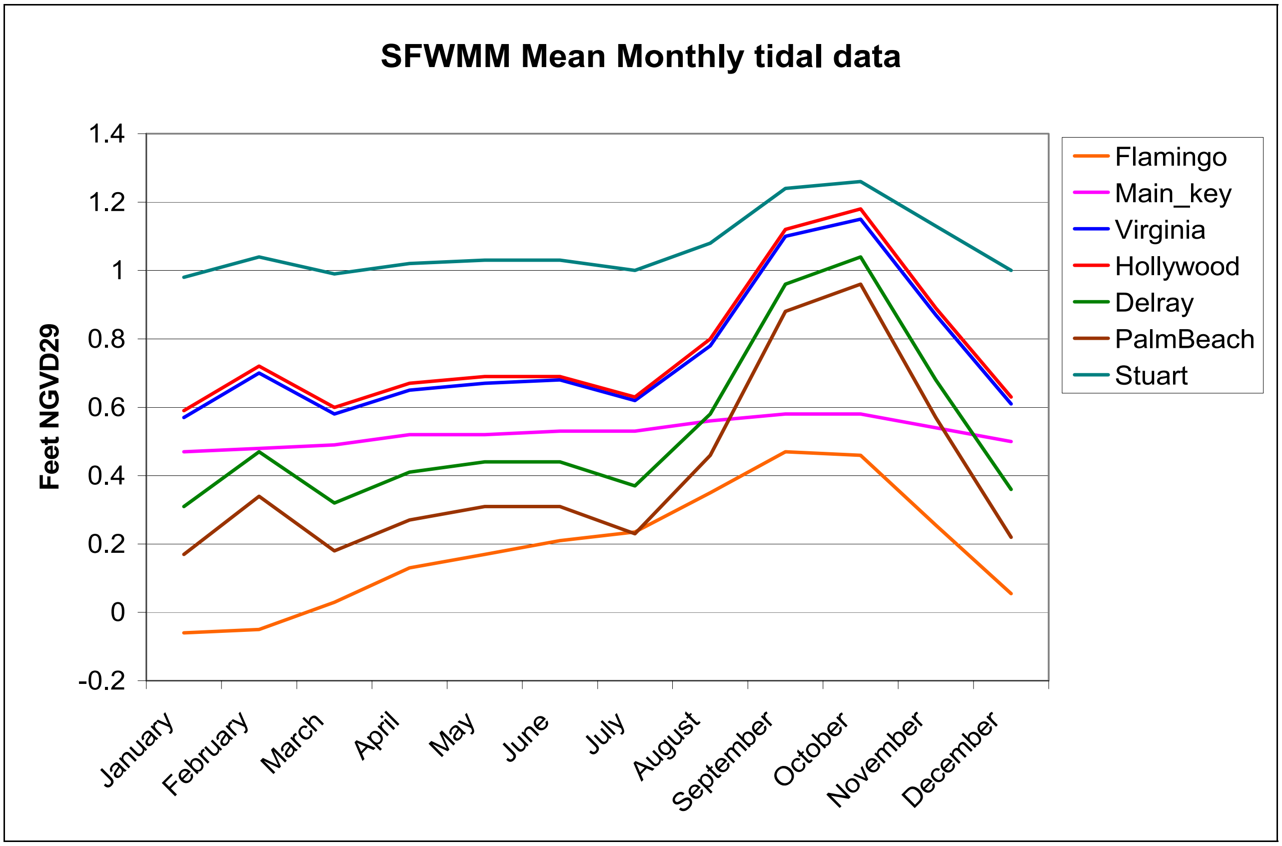

Figure 2.7.3.5 Mean Monthly Tidal Data used to define the South Florida Water Management Model Tidal Boundary

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